Infectious Disease Epidemiology Section
Office of Public Health, Louisiana Dept. of Health & Hospitals
800-256-2748 (24 hr. number), and (504) 219-4563
www.infectiousdisease.dhh.louisiana.gov

WATER BACTERIA

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"Water bacteria" is a loose term used to describe bacteria which are frequently found in water. There are several major categories:

The Gram negative non-fermenters are a group of Gram negative bacteria that develop in aquatic environments, have very simple growth requirements and are usually not very pathogenic to humans. There is also a group called "non fermentative" Gram negative bacteria because they do not ferment glucose (they oxidize it). This group includes Pseudomonas, Stenotrophomonas, Acinetobacter, Flavobacterium and Alcaligenes.

The Vibrionaceae constitute a separate group of Gram negative rods which are fermenters. The group includes Vibrios, Aeromonas and Plesiomonas. These are normal inhabitants of surface water. Other bacteria that are found in water and that are causes of nosocomial infections are **Legionella** and **Mycobacteria**. Vibrios, Legionellas and Mycobacteria are discussed in their respective sections.

Bacteriology

These bacteria are often able to get carbon and nitrogen from a wide range of organic and inorganic substrates. Organic compounds from the plumbing and storage of water and minute amounts of salts are sufficient to support their growth.

Epidemiology

Most people assume that the hot water in their house is pretty safe. Unfortunately, even here lurk Mycobacteria, Legionella, Pseudomonas, Acinetobacter and other potential pathogens. Thus they can easily reach high concentration in water: up to one million colony forming units (CFU) in tap water for some Pseudomonas.

In a moist environment they can survive for a long time: 300 days for *P. aeruginosa* in water; 150 days on a dry filter paper.

These organisms can be found in almost **every moist area of a hospital**. They have been found in distilled water, tap water, sinks, drains, faucet aerators, water fountains, ice machines, hydrotherapy tanks, humidifiers, mouthwash, skin creams, detergents, soap dishes, soaps, antiseptics, mops, contact lens solution, food mixers, kitchen appliances, potted plants and in water baths used to warm solutions. Very strict antiseptic practices are the only methods that can keep these bacteria in check.

Many of these non-fermenters are **naturally resistant to many antibiotics,** including β-lactams and cephalosporins. The mechanisms of resistance vary. Only specially developed β-lactams antibiotics, aminglycosides and some fluoroquinolones are of some use.

Many are also **partially resistant to antiseptics**. In the 1950s when benzalkonium chloride was used to disinfect needles and catheters, outbreaks of Pseudomonas bacteremia did occur. High antiseptic dilution and presence of organic materials in the solution supported growth.

Antiseptic preparations such as chlorhexidine, cetrimide, hexachlorophene and palin soap have been found contaminated with *P. aeruginosa* or Stenotrophomonas. Contamination has also been found, but to a lesser extent in phenolic antiseptics and in povidone-iodine.

Pseudomonas aeruginosa

Pseudomonas aeruginosa is commonly found in all moist environments. The major vehicles used by *P. aeruginosa* to travel the hospitals are food and water**.** Vegetables are the most commonly contaminated food: surveys of raw vegetables served in hospitals showed that *P. aeruginosa* can be isolated from 10% to 45% of salads. Typical concentrations in these salads are 1,000 CFU /gram.

P.aeruginosa is rarely found as a colonizer of normal humans: 0% to 2% on the skin, 0% to 3% on the nasal mucosa, 0% to 5% in the throat and 0% to 25% in stools. After hospitalization and particularly after antibiotic treatment, the rate of carriage increases and may exceed 50% in some patient populations. The most common colonization site is the rectum (80% of colonized patients); the pharynx and peritoneum are less often involved. The concentration of *P.aeruginosa* in stools may be quite high: up to one to ten million CFU per gram of stools.

Hospital personnel rarely acts as a reservoir of *P.aeruginosa* (rates of colonization ≤10% and low concentration). Less than 5% of health care workers caring for colonized patients become colonized. Patient to patient or staff to patient transmission of *P.aeruginosa* via the hands or by other fomites is assumed to occur but has been difficult to prove.

Transmission of *P.aeruginosa* results from contact with environmental sources or patient to patient transmission via the hands of personnel or visitors. Colonized patients serve as an important source of *P.aeruginosa*. When environmental sources are controlled with antiseptics and strict aseptic techniques are practiced, *P.aeruginosa* can be acquired from strains carried in the gut at below detection levels.

Pseudomonas dermatitis and otitis externa outbreaks associated with swimming pool and hot tub use are well described; at least 75 cases during six outbreaks occurred during the 1997 to1998 timeframe. Dermatitis outbreaks usually occur as a result of low water disinfectant levels, a condition that also increases the risk for transmission of other chlorine-sensitive pathogens (e.g., *Escherichia coli* O157:H7 and *Shigella sonnei*) that may cause severe health consequences.

Pseudomonas cepacia

Pseudomonas cepacia derives its name from the latin word for onion (Coepa) because it is the agent of onion soft rot. It can grow on all sorts of media. It multiplies well in tap water and distilled water by utilizing trace elements and very low concentrations of organic material.

It is much less virulent to humans than *P. aeruginosa*. It is virtually non-pathogenic in a healthy individual. Usually it can only infect severely immunodeficient patients. It is very common as an opportunistic pathogen in cystic fibrosis patients.

P. cepacia transmission from colonized patients to others seems to be much more common than for other water bacteria. Cohorting of colonized patients has led to reduction of transmission to non-colonized patients.

P. cepacia infection may be a severe condition. The mortality of cystic fibrosis patients who become colonized is increased two-fold during the first year after colonization. In the Center for Disease Control and Prevention (CDC) National Nosocomial Infections Surveillance (NNIS) survey, *P. cepacia* was considered to have contributed to death in 11% of the cases infected by it.

Stenotrophomonas maltophilia

Stenotrophomonas maltophilia is a Gram-negative rod which causes uncommon but difficult to treat infections in humans. Initially classified as *Pseudomonas maltophilia*, *S. maltophilia* was also grouped in the genus Xanthomonas before eventually becoming the type species of the genus Stenotrophomonas in 1993.

S. maltophilia is ubiquitous in aqueous environments, soil and plants, including water, urine, or respiratory secretions. In immunocompromised patients, *S. maltophilia* can lead to nosocomial infections. *S. maltophilia* frequently colonizes breathing tubes (such as endotracheal or tracheostomy tubes), the respiratory tract and indwelling urinary catheters. Infection is usually facilitated by the presence of prosthetic material (plastic or metal), and the most effective treatment is removal of the prosthetic material (usually a central venous catheter or similar device). The growth of *S. maltophilia* in microbiological cultures of respiratory or urinary specimens is therefore sometimes difficult to interpret and not a proof of infection. If, however, it is grown from sites which would be normally sterile (e.g., blood), then it usually represents true infection.

In immunocompetent individuals, *S. maltophilia* is a relatively unusual cause of pneumonia, urinary tract infection, or blood stream infection; in immunocompromised patients, however, *S. maltophilia* is a growing source of latent pulmonary infections. *S. maltophilia* colonization rates in individuals with cystic fibrosis have been increasing.

S. maltophilia is naturally resistant to many broad-spectrum antibiotics (including all carbapenems), and is thus often difficult to eradicate. Many strains of *S. maltophilia* are sensitive to co-trimoxazole and ticarcillin, though resistance has been increasing. It is not usually sensitive to piperacillin; sensitivity to ceftazidime is variable.

Elizabethkingia meningoseptica

Elizabethkingia meningoseptica, previously known as *Flavobacterium meningosepticum* and *Bethkingia Meningosepticum*, is a gram-negative bacillus that is widely distributed in the sea, lakes, ponds, streams, rivers and in the soil. The appearance of small, oxidate-positive, light yellow-pigmented colonies on blood agar media after 24 hours incubation suggests evidence of this bacterial infection.

E. Meningospetica is not typically considered a human pathogen but it is capable of causing a variety of nosocomial infections in cerebrospinal fluid, blood, skin, respiratory system and other body sites. While *E. Meningospetica* is rarely isolated from clinical specimens, there have been a number of outbreaks associated with this bacterium causing meningitis in newborns - linked to environmental sources, mainly water-containing equipment. High mortality rates and neurological sequelae in surviving neonates often result from these outbreaks. Rarely, it is the cause of nosocomial pneumonia, endocarditis, postoperative bacteremia and meningitis in immunocompomised individuals.

E. Meningospetica is typically resistant to antibiotics that effectively treat other gram-negative bacterial infections; therefore, the current recommendations are to use ciprofloxacin, minocycline, trimethoprim-sulfamethoxaxole, rifampin and novobiocin, which are most often used to treat gram-positive bacteria.

Acinetobacter

Acinetobacter was formerly described as Mima, Herellea or included with the Moraxella or Achromobacter groups. It is widely distributed in nature and among animals. It can be found in virtually 100% of soils or waters. It is also part of the normal flora of animals or of humans. It has been cultured from frozen foods and pasteurized milk.

The most common sites of colonization in healthy individuals are the skin (50%), the pharynx (5%), but also the conjunctiva, urethra and vagina. It is the most common Gram negative bacteria carried by hospital staff. After hospitalization, colonization rates increase: up to 50% of tracheostomy sites are colonized in some hospitals.

Because Acinetobacter is part of the normal flora, its isolation does not always mean that it has a pathogenic role. In a study of patients with Acinetobacter bacteremia, it did not appear that the infection caused any excess mortality beyond what was expected from the underlying conditions.

Sphingomonas

Sphingomonas, a new genus whose name was first proposed in 1990, contains one species that is an occasional human pathogen, ***Sphingomonas*** *paucimobilis*. This organism, formerly known as *Pseudomonas paucimobilis* and CDC group IIk-1, is widely distributed in soil and water, including water sources in the hospital environment. It has been implicated in nosocomial outbreaks associated with contaminated water and contaminated ventilator temperature probes.

S. paucimobilis infections typically occur in immunocompromised persons and can be community as well as nosomonially acquired. This is an organism of low virulence, and recovery from infection is the rule, even in debilitated hosts. There are several reports of *S. paucimobilis* intravascular catheter-associated blood stream infection, and catheter removal was necessary in some cases for cure. Blood stream infection has also been reported in hemodialysis patients and after infusion of contaminated autologous bone marrow. Although ventilator-associated pneumonia has been described, airway colonization was much more common than infection in intensive care unit outbreaks. Peritoneal catheter-associated peritonitis, meningitis, ventriculoperitoneal shunt infection, brain abscess, soft tissue infection, wound infection, adenitis, urinary tract infection, and a variety of visceral abscesses have been reported.

S. paucimobilis is strictly aerobic, oxidase-positive, and catalase-positive. Colonies grow on blood agar but not MacConkey's agar, produce a yellow pigment, and can be misidentified as *Flavobacterium* spp. Despite the presence of a single polar flagellum, a low percentage of cells are actively motile, and motility can be difficult to demonstrate in the laboratory (thus the name paucimobilis).

Most isolates are susceptible to trimethoprim-sulfamethoxazole, imipenem, aminoglycosides, tetracyclines, and chloramphenicol. Third-generation cephalosporins are usually active but not predictably so, and resistance to penicillins and first-generation cephalosporins is common. Although fluoroquinolones were active in some reports, many isolates were resistant to ciprofloxacin in one series.

Other Non-fermenters

Alcaligenes is frequently found in soil and water. In hospitalized patients, it is sometimes a colonizer of the eye, ear and pharynx.

Flavobacterium can survive in municipal water supply in spite of adequate chlorination. It is part of the normal flora of the oropharynx.

Eikenella are normal inhabitants of the human oral cavity and upper respiratory tract.

Achromobacter are difficult to classify.

Vibrionaceae

Aeromonas

Aeromonas is a common freshwater bacteria and a common pathogen of cold blooded animals (snakes and frogs). Aeromonas is also found from estuarine and coastal waters, shellfish, farm animals and vegetables at market.

The main species are *A. hydrophila, A. caviae* and *A.sobria*. Those that are producing an exotoxin may be pathogenic.

Recovered from a sterile site (urinary tract, otitis, cholecystitis), Aeromonas is an obvious pathogen. However when recovered from stools, its pathogenic role is controversial. Infected persons have watery, non-bloody stools with no fever and no constitutional symptoms. Children have more severe symptoms while adults tend to have chronic cramps and diarrhea.

Exposure to ponds and lakes are a risk factor for cellulitis and extra intestinal infections. Drinking untreated water from wells is thought to be a source of GI infection.

Treatment with effective antibiotics (SXT-TMP or tetracyclines), relieve symptoms while treatment with ineffective antibiotics (ampicillin, cephalothin), aggravates symptoms.

Plesiomonas

Plesiomonas shigelloides, a ubiquitous freshwater inhabitant, has been implicated as a cause of acute diarrhea and rarely, serious extraintestinal disease. It is closely related to Proteus, although it is currently classified in the family Vibrionaceae. *P. shigelloides* is the only species in the genus. The organism was originally isolated in 1947. It has been referred to as C27, *Pseudomonas shigelloides*, *Aeromonas shigelloides*, or *Vibrio shigelloides*.

P. shigelloides is a motile, facultatively anaerobic, gram-negative, oxidase-positive bacillus. It is easily isolated from some enteric agars such as MacConkey's agar but does not grow well on a thiosulfate citrate bile sucrose (TCBS) medium. Selective techniques may be necessary for isolation of the organism from mixed cultures, such as the use of bile peptone broth or trypticase soy broth with ampicillin. The organism grows well at 35°C and produces visible colonies (nonhemolytic) within 24 hours. The organism does not ferment lactose on most enteric agars.

P. shigelloides is a water- and soil-associated organism that replicates at temperatures above 8°C. It is found primarily in freshwater or estuary environments within temperate and tropical climates but can exist in seawater during the warm-weather months.

Asymptomatic carriage of *P. shigelloides* is very rare among healthy persons.

The usual vehicles of transmission of plesiomonads to humans are water, food such as oysters, shrimp, or chicken and a variety of animals that may be colonized with the organism. The organism has been acquired during foreign travel.

P. shigelloides is associated with gastroenteritis, but the failure to identify an enteropathogenic mechanism, the lack of an animal model and unsuccessful studies to induce disease in volunteers, make it impossible to firmly establish a causal relationship. Potential virulence factors including a β-hemolysin have been identified, but their significance is unknown.

The clinical presentation of *P. shigelloides*–associated diarrhea varies from a mild self-limited illness to mucoid, bloody diarrhea with fecal leukocytes.

A predominance of a secretory-type diarrhea has been reported, but other series have found a high percentage with a clinical illness compatible with enteroinvasive disease featuring abdominal pain, fever, bloody diarrhea and fecal leukocytes.

The majority of symptomatic patients have either traveled abroad or been exposed to potentially contaminated water or food. Outbreaks have been reported, particularly from Japan.

The role of antibiotics for Plesiomonas–associated diarrhea is uncertain. Antimicrobial therapy did not shorten the duration of fever or diarrhea in Thai children with Plesiomonas–associated diarrhea. On the other hand, in a small nonrandomized Canadian study in which most patients developed Plesiomonas–associated diarrhea after travel abroad, eight of nine treated patients were asymptomatic within two weeks compared with six of fifteen controls ($p < 0.05$).

Most descriptions of **extraintestinal disease** come from individual case reports. These reports include cases of osteomyelitis, septic arthritis, endophthalmitis, spontaneous bacterial peritonitis, pancreatic abscess, cholecystitis and cellulitis. About ten cases of neonatal sepsis with meningitis have been described. Bacteremia is rare and usually occurs in immunocompromised hosts, but bacteremia accompanying gastroenteritis has been reported in a healthy 15-year-old girl.

P. shigelloides is usually susceptible to chloramphenicol, trimethoprim-sulfamethoxazole, quinolones, cephalophorins and imipenem. Because of β-lactamase production, most isolates are now resistant to penicillins including ureidopenicillins, although the β-lactamase inhibitor combinations appear to be active. Susceptibilities to aminoglycosides and tetracycline are variable.

Prevention and Control

1. Minimize contamination from tap water: avoid having tap water standing in patient care areas and areas where medical equipment is stored or supplies prepared.
2. Use sterile water in humidification, respiratory devices and any device using water that may pose a risk to a patient.
3. Sterilize medical equipment properly, particularly endoscopes and reusable components of respiratory devices.
4. Use strict aseptic techniques (handwashing, gloves and appropriate use of barriers) to avoid transfer of bacteria from patient to patient or from colonized site to susceptible site in the same patient (stool or perineum to respiratory tract, for example).
5. Proper disinfection of environmental surfaces with antiseptics diluted at correct concentrations
6. Comprehensive surveillance in Units at risk to identify any cluster of infection and investigation of these clusters.
7. For patients at high risk of colonization by Pseudomonas (severely neutropenic patients), exclude potentially contaminated foods (uncooked vegetables).

Hot Tubs

To reduce the risk for Pseudomonas dermatitis and the transmission of other waterborne pathogens, pool and hot tub operators should:

1. Adhere to pool and hot tub recommendations and regulatory requirements for pH and disinfectant levels
2. Have a thorough knowledge of basic aquatic facility operation
3. Provide training for pool staff on system capabilities, maintenance and emergency alert procedures of remote monitoring systems
4. Closely monitor pool and hot tub free chlorine measurements during periods of heavy bather loading
5. Monitor hot tub disinfectant levels closely because the higher temperatures maintained, serve to dissipate chlorine rapidly
6. Understand appropriate use and effects of cyanurates on disinfection and testing.
7. Remote-monitoring companies should be timely in notifying swimming-facility staff about low disinfectant levels. Swimmers should be educated about the potential for waterborne disease transmission in pools and hot tubs, which could increase advocacy for improved maintenance and monitoring by pool operators.